The Agricultural and Mechanical College of Texas
Department of Oceanography
College Station, Texas

Texas A and M Research Foundation
Project 59

PROGRESS REPORT FOR

QUARTER ENDING 31 DECEMBER 1953

Project 59 has as its objective the measurement of heat,
momentum, and water flux from the sea surface. It is
sponsored by the Office of Naval Research (Project
NR 082-11, Contract N7onr-487, Task Order 5). The work
report herein is of a preliminary nature.

Report prepared 22 March 1954
by
Arnold H. Glaser

John C. Freeman, Jr., Project Supervisor

I. Aims:

The general aims of the project are:

A. To develop instrumentation suitable for the measurement of the flux of heat, momentum, and water vapor from the sea surface.

B. To obtain a sufficient number of measurements of these fluxes to draw quantitative conclusions about the factors involved.

C. To make and analyze measurements of turbulent velocities over a natural land surface, this Project's part of the Air Force Great Plains Turbulence Field Program.

II. Great Plains Field Program.

A. Introduction. By amendment to its contract, dated 12 June 1953 this project was authorized to participate in the Great Plains Turbulence Field Program, sponsored by the Air Force Cambridge Research Center. It was held at O'Neill, Nebraska from 1 August to 12 September 1953. For background information on the report that follows, please consult the Fourth Quarterly Report of this Project.

B. Woods Hole Equipment. After rather extended administrative correspondence, the affair of the irreparable damage in shipping to the Woods Hole Fluxmeter has been brought to a close, giving satisfaction, it is feared, to none of the parties involved. The unfortunate loss of time and material can be blamed on no individual; it is to be hoped that the experience gained in this misadventure will ultimately offset the loss.

C. Data Processing. The task of transferring data from strip charts to IBM punched cards has been completed, and the vast bulk of the necessary computations have been performed. To give some concept of the magnitude of this undertaking, it may be mentioned that some 20,000 data cards have been punched, each bearing the date and time of the observations, an identifying serial number, and two sets of two digit numbers. About 200,00 arithmetical operations have been performed. At present the results of the computations are being tabulated for analysis and publication. Further computations of more advanced type must await careful evaluatioh of the data.

III. Instrumentation.

The watt-hour meters that form the central computing system of the flux meter system described in earlier reports have been delivered. It was

found that their characteristics in no way correspond to those supplied by the manufacturer before delivery. As a result, the equipment which had been made to fit the original specifications must be modified. This is being done at present. It is believed that this change will have no effect on the eventual function of the instrument.

Analysis of the data obtained during the summer at O'Neill, Nebraska, has indicated the desirability of construction of a somewhat more sophisticated form of observing head which will be useful over a somewhat greater range of atmospheric conditions than the one presently in use. For background on the discussion to follow please refer to the First Quarterly Report of this Project.

In that report it was shown that the instantaneous pressure developed by a rotating arm anemometer as described is given by

$$P_1 = \frac{1}{2}\rho \left[\omega^2 R^2 + 2\omega RV \sin\phi \cos\omega t + 2\omega RV \cos\phi \sin\omega t + \frac{V^2}{2} \right.$$

$$\left. - \frac{V^2}{2}\cos 2\phi \cos 2\omega t + \frac{V^2}{2}\sin 2\phi \sin 2\omega t \right]$$

where ρ is the air density, ω is the angular velocity of the rotating arm, R is the radius from the axis of rotation to the hole in the arm, ϕ is the angle of the wind in the vertical and V is its vector speed. t is time.

Let us now bring in a second rotating arm, rotating at the same speed as the first about the same axis, but in the opposite sense. This will produce a fluctuating pressure of form identical to that above, but with the sign of the angular velocity ω reversed.

$$P_2 = \frac{1}{2}\rho \left[\omega^2 R^2 - 2\omega RV \sin\phi \cos\omega t + 2\omega RV \cos\phi \sin\omega t + \frac{V^2}{2} \right.$$

$$\left. - \frac{V^2}{2}\cos 2\phi \cos 2\omega t - \frac{V^2}{2}\sin 2\phi \sin 2\omega t \right]$$

The difference of these two pressures may be measured by the same transducer used to measure the single pressure. It is found to be simply

$$P_1 - P_2 = \frac{1}{2}\rho \left[4\omega RV \sin\phi \cos\omega t + V^2 \sin 2\phi \sin 2\omega t \right.$$

If we now operate on this quantity as previously, multiplying it by $\cos\omega t$ and integrating with respect to time,

$$\frac{1}{T}\int_0^T (P_1 - P_2)\cos\omega t \, dt \cong \overline{\rho\omega RV \sin\phi} = C\omega R \overline{W}$$

-2-

where $\bar{w}$ is the vertical velocity.

Multiplication by $T\cos \omega t$ and integration yields

$$\frac{1}{T} \int_0^T (p_1 - p_2) T \cos \omega t \, dt \cong \rho T \omega R V \sin \phi = \omega R \, \overline{\rho w T}$$

where $\overline{\rho w T}$ is the vertical heat flux.

Multipication by $\sin 2\omega t$ and integration yields

$$\frac{1}{T} \int_0^T (p_1 - p_2) \sin 2\omega t \cong \frac{1}{4} \overline{\rho V^2 \sin^2 \phi} = \frac{1}{2} \overline{\rho u w}$$

where $-\overline{\rho u w}$ is the flux of momentum or the shearing stress.

This form of construction would appear from the analysis above to be considerably superior to the simpler one-arm construction that has already been found fairly satisfactory. This superiority arises from the lack of interfering signals to be integrated by the electronic integrator, and because of cancellation of error signals produced by such effects as the instrument rotating partially in its own wake. This latter effect became significant in the original instrument at low wind velocities.

Mechanical simplicity must be sacrificed, however, for the mathematical and operational elegence of function. A high-speed counter-rotating coaxial drive with provision for conduction of pressure down concentric hollow shafts is being designed, and construction will begin presently.

IV. Administrative

Toward the end of this period some doubt attended the fate of this Project. Initially it was understood that the research would extend over two years, the first year to be devoted to instrument development, the second to an observation program. Inasmuch as no work had been done on the Project during its first few months because of an unexpected personnel shortage, extension without additional funds was granted to the end of calender 1953, with renewal anticipated at that date.

However, the proposal for renewal was not granted, and it appeared as if the project would terminate at the end of the period covered by this report, with part of the work incomplete. Toward the end of the period, a proposal was made for a no additional funds time extension to permit combination of the work of this project with another similar project to be undertaken by the same personnel. This report and work on the project after the end of period covered by this report was held in abeyance until formal notification of this extension was received.

V. Personnel

Dr. Eiichi Inoue, internationally recognized authority on the theory of atmospheric turbulence, joined this project on 7 October. He is on leave from the National Institute of Agricultural Sciences, Tokyo, Japan. A biography is appended.

Mr. Robert L. Smith, statistician, joined the project on a part-time basis on 1 October; he is supervising the punched-card processing of the O'Neill data.

Full Name	INOUE, EIICHI
Born	Niigata Prefecture, Japan, 1917

Training	Tokyo Imperial University, 1937-1941, B.E.
	   Major - Aeronautical Engineering
	Tokyo University, 1946-1951, Post Graduate Course in
	   the Geophysical Institute, Faculty of Science, Sc.D.
	   1952.

Experience	Army Air Force of Japan, 1941-1945, Technichal Officer in
	   the Technical Division of A.A.F. Japan, Tokyo.
	National Institute of Agricultural Sciences, Ministry of
	   Agriculture and Forestry, 1951- , Chief of the Second
	   Laboratory of Physics, Division of Meteorology, Section
	   of Physics and Statistics.

Organizations	Member of Meteorological Society of Japan Member of Japan Society of Aeronautical Engineering Member of Oceanographical Society of Japan Member of Physical Society of Japan

Publications	Some Remarks on the Similarity Law of the Model Experiments
	   of the Atmospheric Phenomena, Sea and Sky, $\underline{24}$, 309, 1944.
	Natural Wind Flow vs. Wind Tunnel Flow, J. Japan Soc.
	   Appl. Mech., $\underline{1}$, 15, 1948.
	On the Structure of Wind Near the Ground, I; II; III; J.
	   Meteor. Soc. Japan, $\underline{28}$, 219; 339; 367, 1950.
	The Application of Turbulence Theory to the Oceanography,
	   J. Meteor. Soc. Japan, $\underline{28}$, 420, 1950.
	On the Turbulent Diffusion in the Atmosphere, I, J. Meteor.
	   Soc. Japan, $\underline{28}$, 441, 1950.
	On the Smallest Turbulon in a Turbulent Flow, Rept. Inst.
	   Sci. Technol., $\underline{4}$, 194, 1950.
	On the Pressure Fluctuations in a Turbulent Fluid, Geophys.
	   Notes, Tokyo Univ., $\underline{3}$, no. 33, 1950.
	On the Temperature Fluctuations in a Heated Turbulent
	   Fluid, Ibid., no. 34, 1950.
	Prandtl Number in a Turbulent Fluid, Ibid., no.35, 1950.
	Interrelation between Turbulent Fields in Ocean and
	   Atmosphere, Ibid., no. 36, 1950.
	On the Structure of Wind Near the Ground Surface, IV; V,
	   J. Meteor. Soc. Japan, $\underline{29}$, 14; 59, 1951.
	On the Turbulent Diffusion in the Atmosphere, II, J. Meteor.
	   Soc. Japan, $\underline{29}$, 246, 1951.
	The Application of the Turbulence Theory to the Large-
	   Scale Atmospheric Phenomena, Geophys. Mag., $\underline{23}$, 1, 1951.
	On the Turbulent Diffusion Phenomena in the Ocean, J.
	   Oceanogr. Soc. Japan, $\underline{7}$, 1, 1951.

Inoue, Eiichi

Publications
(Continued)

The Mutual Interaction of Turbulons in a Turbulent Flow
Field, J. Japan Soc. Appl. Mech., 4, 25, 1951.
Natural Wind Flow vs. Wind Tunnel Flow, II, J. Japan
Soc. Appl. Mech., 4, 27, 1951.
On the Fluctuations in Pressure in a Turbulent Fluid,
J. Japan Soc. Appl. Mech., 4, 87, 1951.
Some Remarks on the Dynamical and Thermal Structure of
a Heated Turbulent Fluid, J. Phys. Soc. Japan, 6,
392, 1951.
Some Remarks on the Vertical Diffusion of Smoke Near
the Ground, J. Meteor. Soc. Japan, 30, 216, 1952.
Interrelations between the Structure of Wind Near the
Ground and Its Observations, J. Meteor. Soc. Japan,
30, 255, 1952.
Turbulent Fluctuations in Temperature in the Atmosphere
and Oceans, J. Meteor. Soc. Japan, 30, 289, 1952.
Some Remarks on the Lagrangian Correlation Coefficient
of Turbulent Diffusion in a Wind Tunnel Flow, J. Phys.
Soc. Japan, 7, 503, 1952.
Influences of the Length of Hot-Wire Anemometer on the
Measurement of Turbulent Flow, J. Phys. Soc. Japan,
7, 508, 1952.
Some Remarks on Lettau's New Theories on the Atmospheric
Surface Layer, J. Meteor., 9, 224, 1952
On the Lagrangian Correlation Coefficient for the Turbulent
Diffusion and Its Application to Atmospheric Diffusion
Phenomena, Geophys. Res. Pap. Cambridge, no. 19, 397,
1952.
Some Measurements of the Wind over Cultivated Fields, I,
J. Agric. Meteor. Soc. Japan, 7, 48, (Coauthor: N. Tani).
On the Structure of Wind Near the Ground, Bull. Nat. Inst.
Agric. Sci. Japan, ser. A, no. 2, 93 pp., 1952.
A Note on the Interrelation between Two Types of Turbulent
Diffusion in the Atmosphere, Proc. 2nd Japan Nat. Congr.
Appl. Mech., 227, 1953.
A Preliminary Note on the Atmospheric Turbulent Diffusion
over Rough Surfaces, J. Meteor. Soc. Japan, 31, 1, 1953.
On the Floating Condition of Particles in a Turbulent Fluid,
J. Japan Soc. Aeron. Enging., 1, 1, 1953.
Some Measurements of the Wind over Cultivated Fields, II,
J. Agric. Meteor. Soc. Japan, 8, 45, (Coauthors: N. Tani
and K. Imai), 1953.
Some Remarks on the Diffusion of a Smoke Puff Floating in
the Atmosphere, Proc. 3rd Japan Nat. Congr. Appl. Mech.,
in press.